DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA

64-11

NOLTR 63-266

ESTIMATION OF HIGH AND LOW
PROBABILITY EED FUNCTIONING LEVELS

3 FEBRUARY 1964

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 63-266

D D
APR 14 1964

TISIA A

ESTIMATION OF HIGH AND LOW PROBABILITY
EED FUNCTIONING LEVELS

By
L. D. Hampton, J. N. Ayres, I. Kabik

ABSTRACT: Predicting very high or low EED response
probabilities usually requires extrapolation from limited
data. Extrapolation errors will be increased by inappropriate
test plans or statistical treatment. Various test plans
are discussed. Possible new prediction techniques are
suggested. The necessity for careful design of experiment
is stressed.

PUBLISHED APRIL 1964

i

NOLTR 63-266   3 February 1964

Estimation of High and Low Probability EED Functioning Levels

The present report, with minor variations, was presented
at the 4th Electric Initiator Symposium, 1 & 2 October 1963.
Because the subject material is of broad interest it warrants
a wider distribution than it might get by appearing only in
the Proceedings of the Symposium. The concepts dealt with
are equally of interest in weapon safety and weapon reliability
considerations.

The work leading to the writing of this report was supported
by Task NOL-443/NWL.

                                        R. E. ODENING
                                        Captain, USN
                                        Commander

                                        C. J. ARONSON
                                        By direction

CONTENTS

REFERENCES

1. "The Prediction of Very-Low EED Firing Probabilities",
   J. N. Ayres, L. D. Hampton, I. Kabik, Proceedings of the
   Second HERO Congress, Philadelphia, Pa., April 30-May 2, 1963.
2. "Statistical Methods in Initiator Evaluation", Franklin
   Institute Laboratories for Research and Development, Interim
   Report No. I-1804-1, Carl Hammer, May 1, 1955.
3. "Characterization of Squib Mk 1 Mod 0: Determination of the
   Statistical Model", NAVWEPS Report 7347, L. D. Hampton,
   J. N. Ayres, 30 January 1961.
4. "Analysis of Sensitivity Experiments when the Levels of
   Stimulus Cannot be Controlled", Abraham Golub and Frank E.
   Grubbs, Journal of the American Statistical Association,
   51 (1956) 257-65.
5. Private Communication from Martin-Marietta to NOL.

I. INTRODUCTION

In this paper the authors wish to address themselves to the problem where, with a limited number of samples, it is desired to predict the stimulus corresponding to an extreme functioning probability level for a given electric initiator population, or conversely the estimated response at a stipulated stimulus. This problem is becoming increasingly important to both the military and the space agencies. In the past the military could frequently tolerate weapons having a relatively large degree of unreliability and then compensate for this unreliability by firing large numbers of weapons to attain the desired target kill; for example, the firing of projectiles or the dropping of bombs in large quantities. However, complex modern weapons, their high cost and their great destructive power often preclude firings in large numbers. High reliability (and safety) must be achieved and demonstrated for the individual weapon. As for space ventures the complexity of operations, the necessity for accuracy, the high cost, the prestige value, and the stake in human lives make it mandatory that components have a high level of reliability and safety.

High reliability (or safety) in the sense that we will use it here is a functioning probability of 99.5% or higher at a specified input level. Such reliabilties are not excessive for electro-explosive devices. Experience based on thousands of manufacturers' firings of conventional primers and detonators show that such reliabilities are in fact usually exceeded by ordinary production techniques. During the course of development, however, it is often necessary to predict the response of EED's to given stimuli. For example, in assessing hazards of electro-magnetic radiation it may be necessary to predict the response at a very low stimulus level. To determine whether a given power supply in a particular weapon is capable of reliably firing an EED it is necessary to estimate the response of the EED to the input stimulus of the power supply.

The direct demonstration of a 99.5% or better response at 95% confidence of an EED to a given stimulus is often too costly in material, time, and manpower to be seriously considered. It would require the firing of approximately 750 items without a failure.

Before discussing the general philosophy for making, logically, the required estimates, some discussion appears warranted about the present most frequently used method. This is the Bruceton method.

It is the authors' observation that the Bruceton test method is being used extensively for determining the response (sensitivity) of electric initiators. When properly used it is

a good method. It is rapid and economical. The algebraic
manipulations required to produce the statistical quantities
are simple to carry out. It is because of these features that
the Bruceton test has found such widespread application.
Unfortunately it has been frequently used in situations where
the results obtained are inaccurate and misleading.

For making studies around the 50% response level the test
is most often highly acceptable and advantageous. When
estimates are made by the Bruceton method beyond the 75% response
level difficulties can be anticipated. The authors have spelled
out in detail the reasons for the difficulty in a paper
presented before the last HERO Congress[1]*. The salient reasons,
without detail, are worthy of repetition:

 a. The Bruceton method gives a very poor estimate
    of the standard deviation. Even Bruceton tests
    of 100 samples will often underestimate the
    true standard deviation by 50 per cent or more.

 b. Since most all of the data are collected between the
    25 and 75% firing points, long extrapolations
    must be made to the points of interest along
    a curve which is usually unknown.

When it is not feasible to demonstrate directly a response
at an extreme firing point, estimates of the response are usually
made by a process of extrapolation and curve fitting. The
extrapolation process is basic to the approach. This principle
should be kept firmly in mind. All of us as technical people
are very familiar with making extrapolations and the principles
involved. The statistical problems are really no different. What
is desired is an extrapolation from measured response points to
points removed from the region of measurement. Our extrapolations
become better as the length of the extrapolation becomes smaller.
They also become better when the general shape of the curve being
extrapolated is known. From the statistical standpoint, when the
response function or distribution function is known in the region
of extrapolation.

There is no single best method for making estimates of
extreme functioning probability points. Various methods are
available for use. Those which can be used for best results
depend on such factors as sample size available, the degree of
accuracy needed, data available from other tests, and the
remoteness of the desired functioning level.

_____

*References are given on page iii.

II. PRESENT SENSITIVITY TESTING METHODS

Sensitivity tests are of different types. Each type has certain advantages and disadvantages. These should be considered to make an intelligent selection of the test to be used. In certain situations one test would be selected while in others a different test would be chosen. We shall consider some of the tests which are frequently used along with their advantages and disadvantages. First, however, it would be wise to state some principles which will be general in their applications.

In most tests the analysis involves fitting a frequency distribution function to the observed data. In other words the test consists of an experiment in which the sensitivity is determined at each of two or more stimulus levels. From these data we attempt to predict either the response at some other level or the level which will have some desired response. In order to do this we must assume some frequency distribution function. One which has been widely used in the explosives field is the log-normal function. Experience has shown that this is a fairly good fit and entirely adequate for many purposes. However, recent work at The Franklin Institute[2] and at the Naval Ordnance Laboratory[3] has shown that the log-logistic function gives a somewhat better fit. Even this is not a perfect fit.

In general, predictions based upon interpolation from observed data are fairly safe since the function assumed in the interpolation will ordinarily coincide closely with the true function over the range of the observed data. On the other hand the assumed and true functions may differ considerably outside this range. For this reason extrapolation is always dangerous because of the uncertainty in the choice of distribution function. The larger the extrapolation the greater the resulting error is likely to be. The use of extrapolation cannot be avoided in estimates of very high or low response points. However it can be kept small by proper choice of test plan at the cost of testing an increased number of items.

A second point to be considered is the possibility of bias. Some tests have a tendency to over or underestimate the quantity which is being determined. This tendency is known as bias. Some bias might be tolerated, if it were in the direction of making a more conservative estimate.

Another point to be considered in planning sensitivity experiments is the allocation of items to the stimulus test levels. A trial made at a stimulus level at which almost all trials are expected to result in fires or fails gives us less information than one made near the fifty per cent point. To obtain an equal amount of information at each level we must

assign larger numbers of items at levels farther from the fifty per cent point. By this method we can give each of the levels equal weight.

Another consideration is the total number of items to be tested. Of course, the larger this number the more information we obtain. This, then, usually becomes a compromise between the amount of information we would like to have and what we can afford to spend in time and money in order to get it. Some tests are more efficient than others in obtaining information from a given number of trials.

One type of test which is quite largely used is the up-and-down or stair-step test, the best known being the Bruceton test. This test concentrates the trials near the fifty per cent point. All, or nearly all, of the data will be from observations concentrated between the 25 and 75 per cent points. The weights of the observations at the test levels will show an even greater concentration around the fifty per cent point. Investigations in England and at the Naval Ordnance Laboratory have indicated that the Bruceton test has a serious bias in the estimation of the standard deviation, giving a value which is too small. The effect of this bias would be to predict too much reliability and safety for an item which is tested in this way. The error becomes even more serious since the concentration of trials near the fifty per cent point makes the prediction of reliability or safety depend upon extreme extrapolation. Consideration of the characteristics of the Bruceton test shows that it is a good test for anyone who is interested in determining the fifty per cent point but a poor test for determining high or low per cent points.

Another test which has some of the characteristics of an up-and-down test is the Bartlett test. Stimulus levels are set up and testing continued at each level until two reversals are observed. A reversal is a fire, or fail, when the other response is expected. The Bartlett plan gives an increasing number of trials as we get farther from the fifty per cent point. Thus the weights of the observations at the different levels are made approximately equal. It also reduces the extrapolation required for very high or low response points and therefore is a good test for making estimates of extreme functioning levels. It is fairly easy to show, however, that estimates of sensitivity obtained by this plan are biased. Sixty per cent of the tests will give estimates of the sensitivity which are too low at the upper end of the range and too high in the lower end. This bias is not as serious as that shown by the Bruceton test since it is in the direction of conservatism. It should be emphasized that the Bartlett test requires very large samples. In two instances[2],[3] the sample sizes were approximately 8000.

A third type of test is one which has been analyzed by Golub and Grubbs[4] of the Ballistic Research Laboratory at Aberdeen, Maryland. In this type of test a comparatively small number of items is tested at different levels of stimuli with possibly only one item at each level. This type of plan is especially applicable to tests in which the stimulus level cannot be exactly controlled but can be measured. Ford Motor Company[5] has recently done some work on a similar type of test. Since the sample size for either of these tests is usually small, the results are subject to the uncertainty always associated with small samples.

Finally, a plan which is quite frequently used is one that has been called the run-down test. This type and the up-and-down tests include most of the sensitivity tests which are made. The plan calls for making a specified number of trials at each of two or more stimulus levels. We shall describe here in detail, as an example of tailoring tests to specific situations, a run-down test plan which calls for testing at two stimulus levels. This plan was devised to determine high probability of firing estimates for electro-explosive devices of one of the Navy's most important missiles. Only 200 EED's per sample were available for test. This test plan was optimized to fit the specific needs but may be useful to others faced with a similar problem. The probability points of interest are estimated by extrapolation based on observed responses measured in the neighborhood of the 65 and 90 per cent points. If we have previous experience with similar items we may use this experience as the basis for choosing these two test levels. Lacking this experience, we can use a short Bruceton test. Suppose that we use twenty of the two hundred items in the preliminary Bruceton test. Then the remaining one hundred eighty are used for the main test at the two levels. Fifty items will be allocated at the expected 65 per cent level, and the remaining one hundred thirty will be tested at the expected 90 per cent level. If, after testing the fifty items at the first level, it appears that the response is much higher than the expected 65 per cent point we can revise our plan by using this as the second level rather than the first. In this case a new level is selected as the first, somewhat nearer the 50 per cent point, and fifty items tested at the new level. The following is a step-by-step procedure for firing the two hundred items.

> a. Fire twenty items in a Bruceton test to obtain preliminary estimates of the mean, m, and the standard deviation, s. A log-transform of the dosage (current, potential, energy) is taken as the stimulus.

b. Compute the first and second test levels as
the mean of the Bruceton test plus 0.4s and
1.3s respectively.

c. Test fifty items at the first stimulus level.

(1) If five or fewer fails are observed,
redefine the first level as the second
and continue firing at this level until
one hundred thirty are tested. Test the
remaining fifty at a stimulus level m + 0.2s.

(2) If more than five fails are observed (the
usual case) test the remaining one hundred
thirty units at the original second level.

The analysis of the data obtained from a test of this kind
would require fitting a frequency distribution function,as was
pointed out earlier in this paper. As was also pointed out the
log-logistic function is the preferable one. The procedure for
fitting this function to these data would be as follows. First,
convert the observed number of fires, x, and fails, y, for each
level into logits by the relation

$$L = \ln \frac{x}{y} \ .$$

Plot these values of L against the stimulus (log-current, log-
potential, or log-energy). Draw a straight line through these
two points. To interpret the graph in terms of per cent response
for any stimulus read the result in logits and change to per
cent by the relation

$$L = \ln \frac{p}{100 - p}$$

where p is the desired per cent.

A test of this general type has the good feature of
minimizing the necessary extrapolation. It is free from bias
such as is found in the Bruceton or Bartlett tests. The items
are allocated to the test levels so as to give nearly equal
weight to the observations. Two hundred items is about as small
a number as can be used in order to give a good estimate of a
high or low per cent point.

III. NEW APPROACHES

NOL is looking for ways for improving extreme-probability
estimation methods by using information in addition to Go/No-Go
firing data.

As has been pointed out, the estimation of very high or low probabilities on the basis of Go/No-Go data always requires extrapolation towards the asymptotic All-Fire and No-Fire limits. The extrapolation is a risky business. Can we avoid this extrapolation? We think that it is possible. By using data from such sources as nondestructive measurements of EED thermal parameters in conjunction with sensitivity data we can interpolate rather than extrapolate.

For instance, we can show with the Mk 1 Squib that a current of 50 milliamperes through the bridge would cause a maximum elevation of the bridgewire temperature above ambient of about 10°Centigrade. By figuring backwards from a maximum acceptable elevation of the bridgewire temperature, we can deduce an even higher maximum current which would be acceptable not only as a safe current but also one which will not deteriorate the EED. In this fashion we can establish a true No-Fire current level.

Once a non-zero No-Fire level is available we should be able to estimate a very low probability of firing by interpolation between the No-Fire level and experimentally observed low-probability firing data.

A similar use of the electro-thermal data in conjunction with limits of variability of EED configuration and explosive ignition temperatures should permit the computation of a finite All-Fire point (provided there are no Q-C defects). With this All-Fire point and appropriate firing data we should be able to interpolate to find a high reliability point.

In either case, the interpolation can be carried out only if some distribution function can be assumed to connect the data. There are many expressions which can be devised to describe a distribution which is (1) approaching zero probability tangentially at a non-zero positive No-Fire point, (2) approaching a probability of 1 at a finite All-Fire point, and (3) a fit through observed firing data. What basis do we have for selecting the proper function?

To handle this problem, we are investigating the field of non-parametric or distribution-free statistics. The general approach in this technique is to find facts which apply to whole classes of distributions. It is assumed, on the basis of experience, that the EED distribution, though unknown, falls in a general class. If appropriate boundaries or limits for the class of distributions can be found then it will be possible to set conservative bounds on the EED probability estimates.

For instance, if it can be assumed that:

(a) The Probability Density Function is unimodal, i.e., the Cumulative Distribution Function (C.D.F.) has a single inflection point which corresponds to the mode above, and

(b) The two distribution functions are zero at the true No-Fire level,

then we can say that a straight line drawn on the C.D.F. from the No-Fire point to the inflection point will always be more conservative for safety estimates than any distribution which satisfies the above criteria. This is because the C.D.F. will always be concave upward in this range.

The trouble with the above example is the difficulty in experimentally locating the point of inflection of the C.D.F.

IV. CONCLUSIONS

We advise caution and forethought in carrying out sensitivity determinations. Ready made test plans (such as those previously mentioned) have been devised to answer specific needs and have been based on assumptions which are often implicit. If these needs and assumptions are not relevant to the current problem, trouble can arise. A cookbook firing plan, applied blindly, can be a waste of time, money, and material.

The experimental and computational procedures should therefore be carefully designed before the investigation is started. The questions to be answered should be clearly stated. All relevant background and previous knowledge should be considered. After an experimental program has been proposed, the interpretations of all foreseeable sets of results should be hypothesized before any firing is commenced. If the possible or likely outcomes are inconclusive, then the experimental program should be modified appropriately. The aid of a statistician throughout this planning stage is very necessary. It will reduce the probability of obtaining useless, errant or meaningless results.

And for results to be useful to those other than the experimenter, the background information, the assumptions and statistical procedures should be a part of the data. They should be given in enough detail to permit reconstruction of the logic used throughout the investigation.

DISTRIBUTION

	Copies
Director of Defense Research & Engineering Department of Defense Washington 25, D. C.	1
Chief of Naval Operations (OP 411H) Department of the Navy Washington 25, D. C.	1
Chief, Bureau of Naval Weapons Department of the Navy Washington 25, D. C. 20360	
DLI-3	2
RRRE-5	1
RUME-3	1
RUME-32	1
RMMP-4	1
RMMO-4	1
RREN-312	1
Director, Special Projects Office Washington 25, D. C. 20360	
SP-20	4
SP-27	1
Chief, Bureau of Ships Department of the Navy Washington 25, D. C. 20360	
Code 423	2
Chief, Bureau of Yards and Docks Department of the Navy Washington 25, D. C. 20360	
Code D-200	1
Chief of Naval Research Department of the Navy Washington 25, D. C. 20360	2
Commandant U. S. Marine Corps Washington 25, D. C. 20380	1
Commander Operational Development Force U. S. Atlantic Fleet U. S. Naval Base Norfolk 11, Virginia	2
Commander U. S. Naval Ordnance Test Station China Lake, California 93557	
Technical Library	2
Code 556	1

	Copies
Director Naval Research Laboratory Washington 25, D. C. Technical Information Section	2
Director David Taylor Model Basin Washington 7, D. C. Dr. A. H. Keil	2
Commander Naval Air Development Center Johnsville, Pennsylvania Aviation Armament Laboratory	1

Commander
U. S. Naval Weapons Laboratory
Dahlgren, Virginia
  Technical Library
  Weapons Lab.
  Terminal Ballistics Lab.
  Code WHR
  W. Orsulak
  L. Pruett
  P. Altman
	2
	1
	1
	1
	1
	1
	1

Commander U. S. Naval Air Test Center Patuxent River, Maryland	1
Commander Pacific Missile Range Point Mugu, California	1
Commanding Officer U. S. Naval Weapons Station Yorktown, Virginia R&D Division	2
Commanding Officer U. S. Naval Ordnance Laboratory Corona, California R. Hillyer	1 1
Commanding Officer U. S. Naval Propellant Plant Indian Head, Maryland Library Division	1
Commanding Officer U. S. Naval Explosive Ordnance Disposal Facility Indian Head, Maryland Library Division	1

2

Copies

Commander
Naval Radiological Defense Laboratory
San Francisco, California   1

Commanding Officer
U. S. Naval Ordnance Plant
Guy Paine Road
Macon, Georgia 31201   1

Commanding Officer
U. S. Naval Ammunition Depot
McAlester, Oklahoma
  R. E. Halpern   1

Commanding Officer
U. S. Naval Ammunition Depot
Waipele Branch
Oahu, Hawaii
  Special Projects Officer   1
  Quality Evaluation Laboratory   1

Commanding Officer
U. S. Naval Ammunition Depot
Navy Number Six Six (66)
c/o Fleet Post Office
San Francisco, California   1

Commanding Officer
U. S. Naval Ammunition Depot
Bangor, Maine
  Quality Evaluation Laboratory   1

Commanding Officer
U. S. Naval Ammunition Depot
Concord, California
  Quality Evaluation Laboratory   1

Commanding Officer
U. S. Navy Electronics Laboratory
San Diego 52, California   1

Commanding Officer
U. S. Naval Underwater Ordnance Station
Newport, Rhode Island   1

Commanding Officer
U. S. Naval Weapons Evaluation Facility
Kirtland Air Force Base
Albuquerque, New Mexico   1

Superintendent
Naval Post Graduate School
Monterey, California   1

3

Copies

Commanding Officer
Naval Torpedo Station
Keyport, Washington   1

Army Material Command
Department of the Army
Washington 25, D. C.
  R&D Division   1

Office of Chief of Engineers
Department of the Army
Washington 25, D. C.
  ENGNB   1
  ENGEB   1

Office of Chief Signal Office
Research & Development Division
Washington 25, D. C.   1

Commanding General
Picatinny Arsenal
Dover, New Jersey
  ORDBB-TH8   1
  ORDBB-TJ1   1
  ORDBB-TK3   1
  ORDBB-TM1   1
  ORDBB-TP1   1
  ORDBB-TP2   1
  ORDBB-TP3   1
  ORDBB-TR2   1
  ORDBB-TS1   1

Commanding Officer
Army Signal R&D Laboratory
Ft. Monmouth, New Jersey   1

Commanding Officer
Office of Ordnance Research
Duke Station
Durham, North Carolina   1

Commander
Frankford Arsenal
Philadelphia 37, Pennsylvania   1

Commander
U. S. Army Rocket & Guided Missile Agency
Redstone Arsenal, Alabama   1

Commanding Officer
Harry Diamond Laboratory
Connecticut Avenue & Van Ness Street
Washington 25, D. C.
  Ord. Dev. Lab.   1
  M. Lipnick (Code 005)   1
  R. Comyn (Code 710)   1
  G. Keehn (Code 320)   4   1

Copies

Chief of Staff
U. S. Air Force
Washington 25, D. C.
 AFORD-AR   1

Commander
Wright Air Development Center
Wright-Patterson AFB, Ohio
 WWAD   1

APGC (PGTRI, Tech. Lib.)
Eglin AFB, Florida   1

Commander
Air Research & Development Command
Andrews Air Force Base
Washington 25, D. C.

Commander
Rome Air Development Center
Griffis Air Force Base
Rome, New York   1

Commander
Holloman Air Development Center
Alamagordo, New Mexico   1

Commanding Officer
Air Force Missile Test Center
Patrick Air Force Base, Florida   1

Commander
Air Force Cambridge Research Center
L. G. Hanscom Field
Bedford, Massachusetts   1

Commander
Hill Air Force Base, Utah
 OOAMA   1

Defense Documentation Center
Cameron Station
Alexandria, Virginia
 TIPCR   20

Office of Technical Services
Department of Commerce
Washington 25, D. C.   100

Director, U. S. Bureau of Mines
Division of Explosive Technology
4800 Forbes Street
Pittsburgh 13, Pennsylvania   1

Copies

Atomic Energy Commission
Washington 25, D. C.
  DMA   1

Lawrence Radiation Laboratory
University of California
P. O. Box 808
Livermore, California
  Technical Information Division   1

Director
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico
  Library   1

Stavid Engineering, Inc.
U. S. Route 22
Plainfield, New Jersey   1

Vitro Corporation
14000 Georgia Avenue
Silver Spring, Maryland   1

Western Cartridge Company
Division of Olin Industries
East Alton, Illinois   1

Denver Research Institute
University of Denver
Denver 10, Colorado   1

Unidynamics
Universal Match Corp.
P. O. Box 2990
Phoenix, Arizona   1

Bermite Powder Company
Saugus, California
  L. Lofiego   1

Field Command, Defense Atomic Support Agency
Albuquerque, New Mexico
  FCDR   2

Defense Atomic Support Agency
Washington 25, D. C.   2

Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
  BRL   1

Copies

Commanding Officer
Engineer Research & Development Laboratory
U. S. Army
Ft. Belvoir, Virginia   1

Commanding General
White Sands Proving Ground
White Sands, New Mexico   1

Sandia Corporation
P. O. Box 5400
Albuquerque, New Mexico 87115   1

Sandia Corporation
P. O. Box 969
Livermore, California   1

Lockheed Aircraft Corporation
P. O. Box 504
Sunnyvale, California   1

Librascope-Sunnyvale
670 Arques Avenue
Sunnyvale, California   1

Director, Applied Physics Laboratory
Johns Hopkins University
8621 Georgia Avenue
Silver Spring, Md.   1

Commanding Officer
Ft. Dietrick, Md.   1

Commanding Officer
Rock Island Arsenal
Rock Island, Illinois   1

Commanding Officer
Watertown Arsenal
Watertown 72, Massachusetts   1

Commanding General
Redstone Arsenal
Huntsville, Alabama
  Tech. Library   1

Commander, Ordnance Corps
Lake City Arsenal
Independence, Missouri
  Industrial Engineering Division   1

Director, USAF Project RAND
  Via: USAF Liaison Office
  The Rand Corp.
  1700 Main Street
  Santa Monica, California   1

Copies

Shock Hydrodynamics, Inc.
2444 Wilshire Boulevard
Santa Monica, California
  L. Zernow

1

Stanford Research Institute
Poulter Laboratories
Menlo Park, California   1

Explosives Research Group
University of Utah
Salt Lake City, Utah   1

Beckman Instruments, Inc.
525 Mission Street
South Pasadena, California   1

Bulova R&D, Inc.
62-10 Woodside Avenue
Woodside 77, New York
  M. Eneman   1

E. I. duPont deNemours
Eastern Laboratories
Explosives Department
Gibbstown, New Jersey   1

Alleghaney Ballistics Laboratory
Cumberland, Md.   1

The Franklin Institute
20th & Benjamin Franklin Parkway
Philadelphia, Pennsylvania   1

Welex Electronics Corp.
Solar Building, Suite 201
16th & K Streets, N. W.
Washington 25, D. C.   1

American Machine & Foundry Co.
1025 North Royal Street
Alexandria, Virginia
  Dr. L. F. Dytrt   1

Atlas Chemical Industries
Reynolds Ordnance Section
P. O. Box 271
Tamaqua, Pennsylvania
  Mr. R. McGirr   1

Grumman Aircraft Engineering Corp.
Weapon Systems Dept.
Bethpage, Long Island, New York
  Mr. R. M. Carbee   1

8

Copies

Jansky & Bailey, Inc.
1339 Wisconsin Avenue, N. W.
Washington, D. C.
  Mr. F. T. Mitchell, Jr.   1

McCormick Selph Institute
Hollister, California
  Technical Library   1

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri
  Security Officer   1

RCA Service Co.
Systems Engineering Facility (E. B. Johnston)
Government Service Department
838 N. Henry Street
Alexandria, Virginia   1

Redel, Inc.
2300 E. Katella Avenue
Anaheim, California
  Library   1

Armed Services Explosives Safety Board
Department of Defense
Room 2075, Bldg. T-7, Gravelly Point
Washington 25, D. C.   1

Flare-Northern Division
Atlantic Research Corporation
19701 W. Goodvale Road
Saugus, California   1

Scientific & Technical Information Facility
Attn: NASA Representative
P. O. Box 5700
Bethesda, Md.   1

National Aeronautics & Space Administration
Goddard Space Flight Center
Greenbelt, Md. 20771   1

Atlas Chemical Industries
Valley Forge, Pennsylvania   1

CATALOGING INFORMATION FOR LIBRARY USE

BIBLIOGRAPHIC INFORMATION

	DESCRIPTORS	CODES		DESCRIPTORS	CODES
SOURCE	NOL technical report	NOLTR	SECURITY CLASSIFICATION AND CODE COUNT	Unclassified - 22	UØ22
REPORT NUMBER	63-266	63Ø266	CIRCULATION LIMITATION		
REPORT DATE	3 February 1964	Ø264	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Electroexplosive	ELEX	Safety	SAFE		
Devices	DEVI	Explosives	EXPL		
Response	RESP	Bruceton tests	BRUC		
Probability	PRBA	Sensitivity	SENV		
Computation	COMA	Primers / Primers	PRIM / PRIM		
Data	DATA	Detonators	DETN		
Extrapolation	EXTP	Exploders	EXPD		
Errors	ERRO	Initiators	INIT		
Prediction	PRED	Components	COMO		
Techniques	TECN	Mathematics	MATH		
Statistics	STAT				
Weapon	WEAP				

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

1. Electro
   explosive
   devices
2. Weapons –
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

1. Electro
   explosive
   devices
2. Weapons –
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

1. Electro
   explosive
   devices
2. Weapons –
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

1. Electro
   explosive
   devices
2. Weapons –
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

1. Electro
   explosive
   devices
2. Weapons -
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

1. Electro
   explosive
   devices
2. Weapons -
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

1. Electro
   explosive
   devices
2. Weapons -
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Abstract card is
unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-266)
ESTIMATION OF HIGH AND LOW PROBABILITY EED
FUNCTIONING LEVELS, by L. D. Hampton and
others. 3 Feb. 1964. 8p. NOL task 443/NWL.

UNCLASSIFIED

Predicting very high or low EED response
probabilities usually requires extrapolation
from limited data. Extrapolation errors will
be increased by inappropriate test plans or
statistical treatment. Various test plans
are discussed. Possible new prediction tech-
niques are suggested. The necessity for care-
ful design of experiment is stressed.

1. Electro
   explosive
   devices
2. Weapons -
   Safety
I. Title
II. Hampton,
    Laurence D.
III. Project

Abstract card is
unclassified.

UNCLASSIFIED